Trans-Lake Washington Project
Washington State Department of Transportation
Sound Transit

Trans-Lake Washington Project
Parametrix, Inc.
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Date: 8-20-02 By: J.m. 080451

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To: **Les Rubstello, WSDOT**
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Date: **August 20, 2002**

Subject: **Final Ventilation and Life Safety Working Paper**

Filing Code: 080451

We are transmitting the following materials:

One (1) electronic copy and one (1) camera ready original of the following report: Final Ventilation and Life Safety Working Paper

Comments:

As required in the Scope of Work, we are transmitting the above report for WSDOT's distribution. However, we request that WSDOT please send us 25 bound copies of the report for final product filing and distribution among key members of the consultant team.

If you have any questions, please feel free to call me at (206) 398-5443.

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Sincerely,

David B. Hilderbrant

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Parametrix, Inc.

cc: Jeff Peacock, Lindsay Yamane, Jane Farquharson, Hans Saxer, Richard Matrisian, Lorie Parker

Washington State
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Ventilation and Life Safety Working Paper

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August 16, 2002
Filing Code: 080451/E-File ID: Final Ventilation & Life Saftey Wrkg. Paper.doc

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ACRONYMS AND DEFINITIONS

AASHTO	American Association of Highway and Transportation Officials
BRT	Bus Rapid Transit
CFD	Computerized Fluid Dynamic
cfm	Cubic Feet Per Minute
CO	Carbon Monoxide
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FHWA	Federal Highway Administration
fpm	Feet Per Minute
HCT	High-Capacity Transit
HOV	High-Occupancy Vehicle
I-5	Interstate 5
MW	Megawatt
OSHA	Occupational Safety and Health Administration
ppm	Parts Per Million
SR	State Route
TSMC	Traffic System Management Center
WSDOT	Washington State Department of Transportation

1. INTRODUCTION

The purpose of this working paper is to describe concepts for ventilation and life safety for tunnels and lids in the Trans-Lake Washington Project (the Project). The concepts and data in this working paper would be used to prepare cost estimates, evaluate environmental, civil and structural impacts.

The Project is located in the State Route (SR) 520 corridor from the Interstate 5 (I-5) interchange at the west end of the alignment to approximately the SR 202 interchange at the east end and includes connections to and from Mercer Corridor at I-5.

The Project includes a number of tunnels and lids. The tunnels provide enclosed roadways for motor vehicle traffic that crosses under a roadway or waterway. The lids are built over the roadway and use the roadway's air rights.

The tunnels and lids are part of the EIS alternatives for this Project. A description of alternatives is included in the Draft Environmental Impact Statement.

There are six key areas in the Project encompassing all tunnels and lids. They include:

- Northbound I-5 on-ramp at Mercer Corridor (Figure 1)
- SR 520 and I-5 interchange (Figure 2)
- Montlake area including (1) the Montlake Boulevard/SR 520 interchange (Figure 3A), (2) the Montlake Boulevard/Pacific Street interchange (Figure 3B), and (3) the Pacific Street connection to SR 520 (a.k.a. Montlake tunnel) (Figure 3C)
- 76th Avenue NE undercrossing (Evergreen Point Road) (Figure 4)
- 84th Avenue NE undercrossing (Figure 5)
- 92nd Avenue NE undercrossing (Figure 6)

The tunnels and lids for each area were evaluated to determine ventilation needs, life safety considerations, and concept-level operations and maintenance. The major elements affecting environmental, civil, or structural elements were identified, including access/egress, vent buildings, and stacks. The concept-level operations include public safety, local agency needs, and maintenance operations. This information includes assumptions and areas for further investigations.

2. BACKGROUND

The tunnels and lids for the Trans-Lake Washington Project were developed as part of the EIS alternatives.

At the concept level of development, many of these elements appear in the cost estimate only. The major elements affecting environmental, civil, or structural elements are further defined in Section 6, Ventilation and Life-Safety Conceptual Design.

In discussing the tunnels and lids for the Trans-Lake Washington Project, reference is made to specific EIS alternatives for consistency of planning. The EIS alternatives include the following:

- No-Action
- Alternative 2: four lanes
- Alternative 3: six lanes: four general-purpose lanes and two bus rapid transit (BRT)/high-occupancy vehicle (HOV) lanes
- Alternative 4: eight lanes: six general-purpose lanes and two BRT/HOV lanes

There are no tunnels or lids proposed for the "No-Action" or 4-lane alternative.

The 6- and 8-lane alternatives include similar tunnel and lidded areas.

Provisions for high-capacity transit (HCT) are not considered for this working paper.

The tunnels and lids have been incorporated in the plan sets for Alternatives 3 and 4.

3. VENTILATION CONCEPTS AND FACILITIES FOR TUNNELS AND LIDS

Ventilation is required to control the build-up of harmful pollutants and to ensure a safe and healthy environment for motorists. Ventilation is also provided for fire fighting and the protection of life and property.

Ventilation and life-safety requirements are based on a combination of local and national standards and on standards of practice involving other tunnels and fire incidents around the world. The recommended standard for roadway tunnel design is provided in the National Fire Protection Association Publication 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways.*

Highway safety design is governed by the Washington State Department of Transportation (WSDOT) standards, including the WSDOT Design Manual, and the American Association of State Highway and Transportation Officials (AASHTO) guidelines. These standards and guidelines would govern tunnel for all alternatives, including sidewall distances for safety walkways and barriers. Emergency egress design is also covered in NFPA 502, which includes safety walkways.

3.1 VENTILATION CRITERIA

Tunnel or lid ventilation is based on meeting acceptable pollution levels in tunnels during normal and congested traffic operation. The system is required to provide fresh air to dilute pollution in the tunnel. The tunnel would be self-ventilating when the piston effect of vehicle traffic at a certain speed is sufficient to generate longitudinal air movement through the tunnel.

Tunnel or lid ventilation is based on the most stringent of the following two conditions: (1) the ventilation rate required for acceptable levels of air pollution in the tunnel during congested traffic operations and (2) the ventilation rate required for control of smoke and hot gases during a fire incident.

Ventilation for air pollution is based on the concentration of carbon monoxide (CO) gas in the tunnel or lid. Dilution of this gas would effectively reduce the levels of other noxious gases associated with the combustion engine. The U.S. Environmental Protection Agency (EPA) and Federal Highways Administration (FHWA) establish recommendations for maximum CO levels in motor vehicle tunnels. Carbon monoxide levels are also regulated on the basis of exposure times; however, the lengths of tunnel or lids proposed for the Trans-Lake Washington Project are not expected to further reduce the allowable level of CO gas for any of the tunnels or lids considered.

Control of heat and smoke during fire fighting varies greatly due to such factors as fire size, tunnel grade, tunnel cross-section, and direction of airflow. Air velocity for smoke control is predicted using the methodology developed by the U.S. Bureau of Mines and by field tests from the Memorial Tunnel Test Program conducted by FHWA. Each method determines the critical velocity at which the buoyant effect of hot gases from a fire is overcome by the longitudinal airflow of the ventilation system. The critical velocity is a measure of system performance necessary for system operation and is included in all systems sized for fire emergencies. NFPA 502 requires tunnels or lids at 800 to 1,000 feet in length to have ventilation systems for fire emergencies.

Control of heat and smoke is also based on the fire size. Vehicles with fuel loading, such as that from gasoline or propane tanker trucks, would be permitted in the mainline section of highway along I-5 and SR 520. Vehicles with a lesser fuel loading would be considered for non-mainline sections of highway through the Montlake Tunnel. This is further discussed in Section 6, Ventilation and Life-Safety Conceptual Design.

Tunnel ventilation for tunnel workers is based on U.S. Occupational Safety and Health Administration (OSHA) standards. Tunnel or lid maintenance is typically conducted during off-peak hours; hence, the ventilation requirement is typically within provisions for general dilution ventilation.

3.2 VENTILATION CONCEPTS

In planning ventilation concepts for each tunnel and lid, both natural and mechanical ventilation systems were considered.

Natural ventilation is desirable where the length or layout of the tunnel or lid does not result in the build-up of pollutants in and around the roadway enclosure. Conditions contributing to the build-up of pollutants include "boat sections" (i.e. tall vertical side walls) in the roadway, which trap gases, and side-by-side tunnels or lids (i.e. minimum separation between tunnels), which tend to funnel polluted air from one area to the next without adequate dispersion. The addition of walls between opposing traffic movements enhances air movement by creating a piston-effect from vehicle movement. These conditions were reviewed and discussed during concept selection for each tunnel or lid.

Where the tunnel or lid has good air dispersion characteristics and the enclosed roadway distances is at 500 feet or less, no supplemental ventilation is recommended. This is based on:

- Preliminary calculations of CO buildup uses assumptions for traffic conditions and estimated emission values of the vehicle mix. Both airflow and pollution values are necessary for a determination of the likely pollution level at the exit to the tunnel or lid. This calculation shows that at approximately 500 feet the air pollution reaches its allowable limit.

- Extending the 500-foot limit may be possible with detailed analysis that takes into account traffic conditions and estimated emission values of the vehicle mix, as well as local conditions including topography, wind, and local air quality receptors. This detailed analysis is required for each specific lid; Because it is time consuming, it is usually performed after a preferred alternative is selected.

- The upper limit is 800 feet. This is the distance where emergency ventilation is a consideration. Per the NFPA 502, tunnels 800 to 1,000 long feet require the full compliment of tunnel safety systems. The lower value was chosen since traffic with hazardous cargo is expected to use this section of roadway.

Of the mechanical ventilation systems considered, the following three primary ventilation systems were reviewed: (1) longitudinal ventilation with jet fans, (2) partial transverse ventilation, and (3) full transverse ventilation. These systems are acceptable for both pollution control during normal and congested traffic operation, as well as for control of smoke and hot gases during a fire incident.

Longitudinal ventilation with jet fans is limited to applications where noise levels are not critical or the location is not in the vicinity of residential neighborhoods. These fans are mounted in the crown of the tunnel or lid and operate to push air or smoke in the direction of traffic movement. The number and size of fans is determined by fire size and number of spares. It is generally agreed that jet fans would create noise levels in the range of 70 to 74 decibels at the entrance to the tunnel or lid.

Partial transverse ventilation uses reversible fans to either supply *or* exhaust ventilation air. The supply air is used for dilution of pollutants during normal operation and the exhaust capability is used for emergency exhaust. These systems have vent stacks. Applications include midtunnel supply or exhaust systems and are typically a consideration for a tunnel retrofit. The vent building can be designed to have minimum impact on the surroundings, and the vent stack can be used to address ground level air quality or noise considerations.

Full transverse ventilation uses separate fans and ductwork to provide supply *and* exhaust ventilation to the tunnel or lid. This system is typically used in long tunnels where it is not practical to introduce air to or from the portal only. The vent building can be designed to have minimum impact on the surroundings, and the vent stack can be used to address ground level air quality or noise considerations. Full transverse ventilation systems typically have portal vent structures at both ends of the tunnel, as well as vent stacks.

3.3 VENTILATION EQUIPMENT

Ventilation fans are rated for high-temperature operation in the event of a fire incident. Fans can be axial or centrifugal. Generally, the axial fans are used for high-capacity, ducted systems; the centrifugal fans are used for lower-capacity, lower-noise levels for midtunnel or lid applications.

Ventilation fans typically require two sources of power derived from separate sources. Each source can be derived from a separate utility feed, or one source can be from the local utility and the other source furnished by a standby diesel generator set. It is assumed that separate feeders are to be provided from separate power sources for fan operation, with the exception of those systems for larger tunnels with local control facilities. Larger facilities are assumed to include standby generator sets for backup of control systems.

3.4 SUPPORT FACILITIES AND VENT STACKS

Fan equipment and tunnel control equipment require support facilities. These facilities can be relatively small for single-lane tunnels with small ventilation and control equipment needs. For large tunnels with multiple fans for emergency operation and foam/deluge systems, support facilities include a variety of onsite services. Maintenance can be part of the local facility or located offsite. Onsite support facilities are necessary for onsite power, traffic management and control, communications, water supply and drainage, and fire apparatus. This is further discussed in Section 6, Ventilation and Life-Safety Conceptual Design.

Maintenance space can include garage and loading dock, electrical shop, communications shop, welding shop, supervisor's office, break room, toilet area, and locker area. Additionally, space is needed for off-street parking for employees, shipping and receiving, and temporary storage.

Vent stacks are located away from residential or commercial areas to the maximum extent practical. In all cases, the stacks are estimated to be 20 feet above surrounding structures or at treetop levels. Noise levels would be attenuated in fan rooms to meet local ambient requirements at the vent stack.

3.5 AREAS OF FUTURE STUDY

The following are areas of future study:

- Any habitable building located within a distance of one tunnel width, estimated at 60 to 120 feet, should be reviewed for long-term ambient air quality standards.

- Where vent stacks are to be provided, stack height is based on providing a discharge at treetops. Additional testing and modeling is needed to provide specific recommendations for stack height and location.

- In-depth analysis is necessary to better define emission values and the vehicle mix of traffic. This would affect conditions at the lid portals and stack. Vehicle emissions are typically modeled 3-dimensionally to take into consideration any spatial requirements for pollution and to made a determination that the long term effects of pollution take into account topography and wind and results in acceptable values to the nearest air quality receptors.

- In-depth analysis is required for tunnel ventilation to better define parameters and understand probable response scenarios. Such analysis can be conducted with computers using computerized fluid dynamic (CFD) analysis that three-dimensionally analyzes the movement of smoke and heated gases and determines likely effects of response times on system and tunnel performance.

- Ventilation of flyer stop platforms would require a determination of the maximum allowable concentration of carbon monoxide gas at the platform area. We have assumed the largest exposure time as 60 minutes and the level of CO as 35 ppm. This would require a separate source of ventilation to achieve improved air quality over peak-hour ambient conditions at the roadway level.

4. LIFE-SAFETY FOR TUNNELS AND LIDS

In addition to ventilation requirements, the tunnels and lids for the Trans-Lake Washington Project were evaluated for life-safety requirements.

4.1 FIRE DETECTION

Fire detection is to be provided for all lids and tunnels longer than 300 feet per NFPA 502. Fire detection would typically include smoke/heat detectors in conjunction with cameras, emergency phones or pull-alarm stations to alarm and subsequently verify the fire incident.

4.2 COMMUNICATIONS SYSTEMS

All new facilities would be connected to WSDOT's fiber network for communications and coordination between the central control facility at Dayton Avenue and other tunnels.

4.3 TRAFFIC CONTROL

NFPA 502 requires traffic control for tunnels and lids exceeding 300 feet in length. These traffic control systems must provide a means to stop approaching traffic from entering the tunnel following activation of a fire alarm within the tunnel. Systems such as illuminated signs or variable messages signs would be displayed at the entrance of the tunnel or lid.

Tunnel and lids more than 800 feet long require more extensive traffic-control measures per NFPA 502, since these tunnels and lids are designed for a fire emergency. In addition to stopping approaching traffic from entering the tunnel, traffic control is also required to stop traffic from entering the direct approach to the tunnel, to control traffic within the tunnel, and to clear traffic beyond the fire site after a fire alarm within the tunnel has been activated.

4.4 FIRE APPARATUS

Fire apparatus for fighting fires would be coordinated with the local agency as part of emergency response planning. Such equipment might include special extinguishers, vehicles to effect retrieval and removal of disabled vehicles, radios, command/control consoles, etc. This equipment is to be provided for those tunnels and lids where emergency response and emergency ventilation is required for tunnels and lids greater than 800 feet long.

4.5 STANDPIPE AND WATER SUPPLY

Tunnel and lids require standpipe and water supply systems for fire suppression. NFPA 502 requires systems for tunnels and lids exceeding 300 feet in length. This equipment would be provided with all tunnels and lids and is incidental to the concept-level design.

4.6 FOAM AND DELUGE SYSTEM

Tunnels and lids are to be provided foam/deluge systems where tunnels have emergency ventilation systems by Code and where tunnels or lids are expected to have unrestricted tunnel traffic including tanker truck traffic. NFPA 502 requires full safety standards be applied to tunnels in excess of 800-1000 feet.

It is the understanding of the Trans-Lake Washington Project that the SR 520 corridor would be used for unrestricted tunnel traffic including tanker trucks with flammable cargo. The use of foam/deluge systems for unrestricted tunnel traffic is similar to that provided for the I-90 tunnels. This is a Seattle Fire Department requirement.

It is further recommended that tunnels and lids that can limit tanker truck traffic to surface routes be provided with hazardous cargo restrictions. This minimizes the life-safety risk to motorists in tunnels and lids. This is further discussed in Section 6, Ventilation and Life-Safety Conceptual Design for the Montlake tunnel.

4.7 PORTABLE FIRE EXTINGUISHERS

Tunnels and lids are to be provided portable fire extinguishers for car fires and as a first defense for more serious events involving trucks and other vehicles. NFPA 502 requires provisions for fire extinguishers in tunnels and lids exceeding 300 feet in length. This equipment would be provided with all tunnels and lids and is incidental to concept-level design.

4.8 TUNNEL DRAINAGE SYSTEMS

Tunnels and lids with ventilation systems designed for fire emergencies are to be provided with a drainage systems to collect, store, or discharge hazardous or flammable effluent. The drainage system is also designed so that spills of hazardous or flammable liquids cannot propagate along the length of the tunnel. The collection and discharge of foam product from the tunnel deluge system will be reviewed during preliminary engineering.

4.9 EMERGENCY EGRESS

Safe egress during a fire emergency is required by NFPA 502. The standard provides: (1) emergency exits spaced so that the travel distance to an emergency exit is no greater than 1,000 feet and (2) by cross passageways (between tunnels) spaced no farther than 660 feet apart. Cross passageways are protected with self-closing fire door assemblies, have a minimum 1-hour rating, and shall have a walkway with minimum clear width of 3 feet, 6 inches continuous the entire length of the tunnel terminating at surface grade. Walkways shall be protected from oncoming traffic by either a curb, change in elevation, or barrier.

Tunnel and lids were reviewed for safe egress. Where ventilation structures are to be provided, emergency egress/stairs to grade were combined with these structures.

5. CONCEPT-LEVEL OPERATIONS AND MAINTENANCE

The tunnels and lids for the Trans-Lake Washington Project include features in support of concept-level operations and maintenance. These were provided to determine the impacts on civil and structural layouts.

5.1 PUBLIC SAFETY

Public safety is included here to address building requirements for public areas, such as flyer stops and bicycle and pedestrian paths. The following shall apply:

- Suitable means are to be provided for access and egress; this includes access stairs as well as handicapped access.
- Ventilation is to be provided for enclosed spaces; where the space is open to atmosphere and where pollution is not likely to build up to unacceptable levels, no ventilation is required.
- Fire protection is to be provided by means of a standpipe system and fire extinguishers; this allows the fire department the means for fire fighting and is consistent with underground public areas, including the King County Metro Bus Tunnel.

5.2 PEDESTRIANS AND BICYCLES

Over and under pedestrian and bicycle crossings are included in the Project. For conceptual planning, it is expected that gates and cameras would be provided for below-grade structures.

Ventilation at tunnel structures for pedestrian and bicycle crossings is not provided since the air quality at the entrance to the crossing is expected to meet long-term ambient air quality requirements by design with setbacks and landscape.

No roadways at tunnels or lids have combined pedestrian or bicycle traffic. Introducing pedestrian or bicycle traffic creates safety issues as well as air quality issues. All bicycle and pedestrian facilities should be separated from roadway sections.

5.3 LOCAL AGENCY NEEDS

Fire department access is to be provided as necessary. The fire department can access the affected roadway from any intersection or on/off ramp. Use of counterflow operation (i.e., moving opposite to the normal direction of traffic) is permissible depending on circumstances and at the discretion of the fire department.

Both eastbound and westbound lanes are served by on-ramps to SR 520. However, to permit emergency crossover between westbound and eastbound lanes on SR 520, a moveable barrier should be provided to aid in bringing fire-fighting equipment from the eastside to eastbound lanes.

5.4 OWNER AND OPERATOR OPERATIONS AND MAINTENANCE

It is expected that WSDOT would operate and maintain equipment for the tunnels and lids. Maintenance operations are assumed to be conducted out of existing WSDOT facilities.

All tunnels and lids having fire suppression and control systems are expected to tie into a local control center as well as WSDOT's Traffic System Management Center (TSMC) at Dayton Avenue. The local control centers are located at the ventilation building. The local control centers allow system operation for testing and in the event the TSMC at Dayton Avenue is not operational.

6. VENTILATION AND LIFE-SAFETY CONCEPTUAL DESIGN

6.1 APPLICABLE TUNNELS AND LIDS

The following are tunnels and lids to be covered in the Ventilation and Life-Safety Conceptual Design:

- Mercer Corridor and I-5:
  - New I-5 northbound on-ramp at Mercer Corridor
- I-5 and SR 520 interchange:
  - Existing southbound and eastbound tunnel becomes HOV lane (Alternatives 3 and 4)
  - New southbound and eastbound but-and-cover tunnel (Alternatives 3 and 4)
  - New westbound to northbound cut-and-cover tunnel (Alternatives 3 and 4)
  - Lid over I-5 and SR 520 (Alternatives 3 and 4)
- Montlake Area:
  - Montlake Blvd/SR520 Interchange: Lid with flyer stop (Alternatives 3 and 4)
  - Montlake Blvd/Pacific Street Interchange: Lid with Bus Stops (Alternative 4 only)
  - Pacific Street Connection to SR520 (a.k.a. Montlake Tunnel): Tunnel under Lake Washington Ship Canal (Alternative 4)
- 76th Avenue NE (with bus flyer stop) (Evergreen Point Road):
  - Lid with flyer stop (Alternatives 3 and 4)
- 84th Avenue NE
  - Lid (Alternatives 3 and 4)
- 92nd Avenue NE (with bus flyer stop)
  - Lid with flyer stop (Alternatives 3 and 4)

6.2 TUNNELS AND LIDS: MERCER CORRIDOR AND I-5

6.2.1 New I-5 Northbound On-Ramp at Mercer Corridor

The tunnel section for EIS Alternative 3 and 4 has a single 15-foot traffic lane and 8-foot and 4-foot shoulders for a total width of 27 feet. The tunnel length is approximately 700 feet, with a +5 percent grade for the first 200 feet and approximately 1 percent grade thereafter. The minimum air requirement is based on a maximum CO concentration of 120 ppm.

The ventilation concept is ceiling-mounted jet fans, one at either end of the tunnel approximately 100 feet from the portal. Clearance requirements are 16.5 feet for the tunnel envelop plus 5.25 feet for fan mounting, for a total of approximately 22 feet. Portal areas are not located near residential areas where noise and air pollution are likely to create a problem.

Support facilities include space for electrical equipment, communications, and CO-detection equipment.

Traffic control would require means to stop approaching traffic from entering the tunnel, as well as signage to stop traffic from entering the direct approach to the tunnel. A gate for blocking entering traffic to the on-ramp is recommended.

A standpipe, portable fire extinguishers, and communications equipment are to be provided in the tunnel.

Emergency egress is located at the tunnel portals.

6.3 TUNNELS AND LIDS: I-5 AND SR 520 INTERCHANGE

6.3.1 Existing Southbound and Eastbound Tunnel Becomes HOV Lane

The tunnel section for EIS Alternative 3 and 4 has a single 12-foot traffic lane and a total width of approximately 25 feet. The reversible HOV lane has a covered roadway, approximately 700 feet long with a -7 percent grade and a +5.5 percent grade to create a tunnel low point. The minimum air requirement is based on ventilation for both normal and emergency ventilation.

This is an existing tunnel with gravity vent at midtunnel. The existing gravity vent is an opening in the ceiling of the tunnel that allows fumes and warmer gases to rise (buoyant effect) and escape to atmosphere. The gravity vent also permits smoke and hot gases from a fire incident to escape to atmosphere. Such a configuration is used for short tunnels or where the tunnel is crowned to permit gases to collect to aid in the exhaust. This configuration has also been shown to be very effective in fire incidents where the smoke and hot gases are effectively stopped from spreading along the crown of the tunnel by the tunnel opening.

The new ventilation concept could be a midpoint exhaust using tunnel exhaust fans or a system of jet fans. The midpoint exhaust has the advantage of using the existing facility to support the upgrade. The disadvantage is the accessibility of the site and potential vent stack at the edge of the lid. The use of jet fans would eliminate the need for the vent stack but would require widening the tunnel in at least two sections to accommodate the fans. The final selection should be made during preliminary engineering.

Support facilities include space for electrical equipment, communications, and CO-detection equipment.

Traffic control would require means to stop approaching traffic from entering the tunnel, as well as signage to stop traffic from entering the direct approach to the tunnel. A gate for blocking entering traffic to the on-ramp is recommended.

A standpipe, portable fire extinguishers, and communications equipment are to be provided in the tunnel.

Emergency egress is located at the tunnel portals.

For the midtunnel exhaust option, a 50-foot-by-50-foot enclosure for fan and electrical equipment would be required. The ventilation stack would be incorporated into the lid or discharged horizontally at one end of the lid.

6.3.2 New Southbound and Eastbound Cut-and-Cover Tunnel

The tunnel section for EIS Alternatives 3 and 4 has a single 12-foot traffic lane and a total width of approximately 25 feet. The lane has covered roadway approximately 1,450 feet long with a -5 percent grade and a +7 percent grade to create a tunnel low point. The minimum air requirement is based on ventilation for both normal and emergency ventilation. This is a new tunnel that parallels the reversible HOV lane described in the previous section.

The ventilation concept could be a midpoint exhaust using tunnel exhaust fans or a system of jet fans similar to the parallel tunnel for the southbound to eastbound HOV lane. The mid-point exhaust provides all fan equipment at a central facility. The use of jet fans would eliminate the need for the vent stack but would require widening the tunnel in at least two sections to accommodate the fans. The final selection should be made during preliminary engineering. The ventilation system would be designed for a fire incident, including a tanker-truck fire.

Support facilities include space for electrical equipment, communications, CO-detection equipment, and a drainage system for fire water collection and discharge.

Traffic control would require means to stop approaching traffic from entering the tunnel, as well as signage to stop traffic from entering the direct approach to the tunnel. A gate for blocking entering traffic to the on-ramp is recommended.

A standpipe, portable fire extinguishers, and communications equipment are to be provided in the tunnel. Since the ventilation system is designed for a fire emergency, a foam/deluge system is to be provided.

Emergency egress is located at the tunnel portals and at the midpoint of the tunnel.

For the midtunnel exhaust option, a 50-foot-by-50-foot enclosure for fan, electrical equipment, and foam/deluge system would be required. The ventilation stack would be incorporated into the lid or discharged horizontally at one end of the lid.

As a further recommendation, it is suggested that the ventilation enclosure for the two tunnels that are side-by-side be combined into one; this would reduce the overall impact of siting equipment and vent stack, as well as provide improved maintenance with fewer pieces of equipment.

6.3.3 New Westbound and Northbound Cut-and-Cover Tunnel (Alternatives 3 and 4)

The tunnel section for EIS Alternatives 3 and 4 has a single 15-foot traffic lane and a total width of approximately 27 feet. The tunnel has covered a roadway approximately 800 feet long with a +5 percent grade to level condition at the exit portal. Part of this would be cut-and-cover construction and part is the lid structure over the right-of-way. At least a portion of the roadway is expected to be at-grade, open on one (or both) sides, and situated under the lid structure.

This tunnel does not require ventilation for fire life-safety purposes based on distance requirements short of 800 to 1,000 feet, the rising grade in the direction of travel, and the following mitigating considerations. The openness of a section of roadway permits smoke and pollutants to be dispersed in the larger cross-sectional area of the lid structure. Although the piston effect of moving vehicles during normal operation is reduced by the absence of sidewalls, the larger (cross-sectional) area of the lid structure would generally allow air currents to move freely to disperse smoke and pollutants.

This tunnel does require ventilation for normal operating purposes. The portion of the roadway in the covered area exceeds the 500-foot recommendation for self-ventilation.

Support facilities include space for electrical equipment, communications, and CO-detection equipment.

Traffic control would require means to stop approaching traffic from entering the tunnel and/or signage to stop traffic from entering the direct approach to the tunnel. A gate for blocking entering traffic to the on-ramp is recommended.

A standpipe, portable fire extinguishers, and communications equipment are to be provided in the tunnel.

Emergency egress is located at the tunnel portals.

6.3.4 Lids over I-5 and SR 520

This includes lids surrounding I-5, 10th Avenue, and Boyer Avenue. The lids along I-5 are approximately 400 feet long, 10th Avenue has lids 400 feet long, and Boyer Avenue has lids 150 feet long.

Lidded roadways along I-5 and SR 520 are expected to be self-ventilating. Lids with separate walls between opposing traffic would make these lidded roadways more efficient for purging air during normal operation. This characteristic together with reduced tunnel length, straight roadway section, and large cross-sectional areas for wind currents are expected to satisfy ventilation needs.

Traffic control would require means to stop approaching traffic from entering the lid.

A standpipe, portable fire extinguishers, and communications equipment are to be provided in the lid.

Emergency egress is located at the portals.

6.4 TUNNELS AND LIDS: MONTLAKE AREA

6.4.1 Lid over SR 520 with Flyer Stop

The lid for EIS Alternative 3 and 4 includes six lanes at 12 feet per lane with 10-foot shoulders and a flyer stop for a total width of 260 feet. The tunnel length is approximately 500 feet with an eastbound +0.5 percent grade.

The lid does not require ventilation for fire life-safety purposes or for normal operating purposes because at 500 feet long it is self-ventilating. During emergencies, motorists escape to safety via tunnel portals.

Traffic control would require means to stop approaching traffic from entering the lid.

A standpipe, portable fire extinguishers, and communications equipment are to be provided in the lid.

Emergency egress is located at the portals or platform stairways.

The Montlake area also has a flyer stop for BRT on SR 520. The bus platform is at the same elevation as mainline traffic and is served at a minimum by stairways and elevator access for handicapped users.

No typical conceptual design for BRT stations located under lids has been developed. Only probable footprint requirements for BRT stations have been identified to date. Therefore, system requirements for BRT station ventilation facilities and emergency ingress and egress have not yet developed. Fire/life safety costs for BRT stations cannot be estimated at this time. All the requirements for ventilation and safety listed below are minimum requirements.

Ventilation for the flyer stop is determined based on long-term passenger exposure to background CO levels at roadway level during congested traffic conditions. For this reason, supplemental ventilation needs to be provided to the platform. The supplemental ventilation is to be provided by a vent building located adjacent the elevator shaft.

The bus platform is to be provided fire protection by both standpipes and fire extinguishers. Emergency egress for the bus platform should be away from the platform in the direction of bus movement.

6.4.2 Lid over Pacific Street with Bus Stop

Traffic control would require means to stop approaching traffic from entering the lid.

A standpipe, portable fire extinguishers, and communications equipment are to be provided in the lid.

Emergency egress is located at the portals or platform stairways.

The Montlake area has a flyer stop for BRT on Pacific Avenue. The bus platform is at the same elevation as the mainline traffic (at below grade location) and is served at a minimum by stairways and elevator access for handicapped users.

No typical conceptual design for BRT stations located under lids has been developed. Only probable footprint requirements for BRT stations have been identified to date. Therefore, system requirements for BRT station ventilation facilities and emergency ingress and egress have not yet been developed. Fire/life safety costs for BRT stations cannot be estimated at this time. All the requirements for ventilation and safety listed below are minimum requirements.

Ventilation for the flyer stop is determined based on long-term passenger exposure to background CO levels at roadway level during congested traffic conditions. For this reason, supplemental ventilation needs to be provided to the platform. The supplemental ventilation is to be provided by a vent building located adjacent the elevator shaft

The bus platform is to be provided fire protection by both standpipes and fire extinguishers. Emergency egress for the bus platform should be away from the platform in the direction of bus movement.

6.4.3 Tunnel under Lake Washington Ship Canal (a.k.a. Montlake Tunnel)

The tunnel section for EIS alternative 4 includes two directions each having two 12-foot lanes with 8- and 4-foot shoulders, a raised walkway, 3.5-foot-wide cross passageways, and 1 feet 6 inches for a center wall, for a total (internal) width of approximately 85 feet. The tunnel height is 16 feet 6 inches with 2 feet 6 inches of headroom for message signs, signals, and lighting. The tunnel length is approximately 4,520 feet with 11 percent grades both approach and leaving sunken tunnel section under the Lake Washington Ship Canal. Both the eastbound and westbound lanes are likely to experience congested traffic during daily commuter peak-hour periods and during special events at the University of Washington.

There is a foam system proposed for the Montlake Tunnel and a reduced design fire size since tanker trucks are not expected to use this tunnel. This assumption is based on this location having alternative roadways available that can be used by commercial vehicles and tanker trucks in lieu of the tunnel. Flammable materials would be allowed to exit at Montlake Boulevard.

The Montlake tunnel is expected to have fire detection, communications, traffic control, fire apparatus, standpipe and water supply, portable fire extinguishers, drainage systems, and support facilities.

Support facilities would be located at or near the tunnel fan room on the north side of the Lake Washington Ship Canal.

The Montlake Tunnel has significant roadway slopes — approximately 11 percent — both approaching and leaving the section of sunken tunnel in the Lake Washington Ship Canal. This creates additional considerations for buoyant smoke and heated gases, which would tend to rise in the tunnel and follow the ceiling toward motorists stopped in the tunnel. This is further compounded by congested traffic and the type and size of fire.

The design fire is proposed to be 50 MW for commercial truck traffic, excluding tanker trucks. If the local authorities mandate higher fire rating due to the expectation that tanker trucks would be allowed to use this tunnel, then additional fire precautions and system ventilation sizing would be required.

Based on the above and the expectation that smoke and heated gases would be difficult to control during a 50 MW fire, the ventilation system is designed for rapid detection and response. The use of jet fans is proposed to ensure longitudinal movement during all periods of operation or at the discretion of the tunnel operator and local authorities. Longitudinal air movement would provide control of smoke and heated gases during initial stages of a fire and provide time to bring the full ventilation equipment up to operating condition.

For conceptual planning purposes, the ventilation system is a full transverse-type with both supply air and exhaust air provided to the tunnel. The normal ventilation requirement is approximately 140,000 cubic feet per meter (cfm), based on estimates of vehicle mix and emissions.

The emergency ventilation requirement is based on a 50 MW fire. We have estimated the tunnel critical velocity to be 490 feet per minute (fpm) and a total estimated ventilation requirement to be 360,000 cfm.

To achieve a ventilation rate of 360,000 cfm in the longitudinal direction of traffic flow, it is expected that the two ventilation buildings, one on either side of the Lake Washington Ship Canal, would operate together. The two ventilation buildings would establish longitudinal airflow with a combination of supply and exhaust, whereby one building would supply air to the tunnel while the second building exhausts air. The combination of supply and exhaust would result in a push-pull effect in the tunnel and establish longitudinal airflow. Also the exhaust capacity of the two ventilation systems could be brought to bear on a single fire in one of the two tunnels. Since the exhaust duct connects the eastbound and westbound tunnels, the system would damper off one tunnel and would allow more air to be exhausted from the other tunnel.

The ventilation system for the Montlake Tunnel consists of two ventilation buildings. Each ventilation building has four axial fans — two supply fans and two exhaust fans — each capable of delivering 175,000 to 200,000 cfm to the tunnel ventilation system. Two ventilation buildings are necessary since there is no ventilation ductwork to bridge the two ends of the tunnel at the sunken tube. Each ventilation plant is expected to be located in the excavated cut above the tunnel section.

Tunnels would include cross-passageway spacing at no greater than 660-foot spacing. Cross passageways are to be protected with self-closing fire door assemblies having a minimum 1-hour rating and a walkway with minimum clear width of 3.6 feet, continuous the entire length of the tunnel, terminating at surface grade.

Support facility for the Montlake tunnels would include the ventilation buildings with axial fans together with lay-down areas, electrical switchgear, communication equipment areas, and local control center. The below-grade portion of the structure would include axial fans for tunnel ventilation and ductwork, with all appropriate transitions between the fan assembly and the tunnel longitudinal ductwork. A basic fan room layout is shown in Figure 1. The below-grade portion of the ventilation structure is intended to sit on the tunnel structure to minimize excavation requirements.

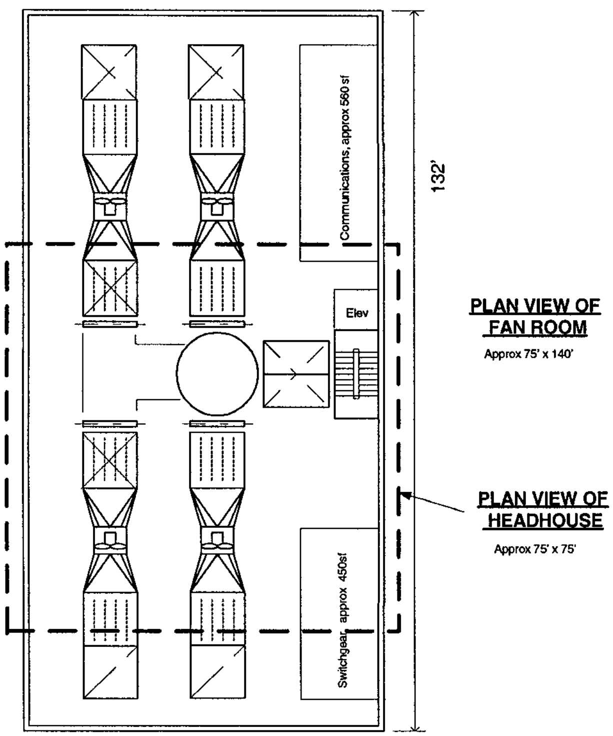

Figure 1: SR 520 Tunnel Ventilation Facility

The ventilation building is expected to have two levels, with one level located at-grade. The at-grade portion of the structure would include air intake louvers, the ventilation stack, and access to the building. A minimum support facility is envisioned; however, consideration should be given to operations planning and maintenance personnel who may have additional requirements for office areas, concession area or lunchroom, equipment removal, truck storage, and other considerations.

6.5 LID AT 76TH AVENUE NE CROSSING

The lid section for EIS Alternatives 3 and 4 includes either six or eight lanes at 12 feet per lane with 10-foot and 8-foot shoulders for a total approximate width of either 190 feet or 214 feet, respectively. The tunnel is approximately 500 feet long with a northbound +0.5 percent grade for the first 200 feet and approximate –1 percent grade thereafter eastbound. The westbound grade is reversed.

These lanes do not require ventilation for fire life-safety purposes or for normal operating purposes because, at 500 feet long, it is self-ventilating. During emergencies, motorists escape to safety via tunnel portals.

Traffic control would require means to stop approaching traffic from entering the lid.

A standpipe, portable fire extinguishers, and communications equipment are to be provided in the lid.

Emergency egress is located at the portals or platform stairways.

The 76th Avenue NE Crossing (Evergreen Point Road) also has a flyer stop for BRT. The bus platform is at the same elevation as the mainline traffic (at below grade location) and is served as a minimum by stairways and elevator access for handicapped users.

No typical conceptual design for BRT stations located under lids has been developed. Only probable footprint requirements for BRT stations have been identified to date. Therefore, system requirements for BRT station ventilation facilities and emergency ingress and egress have not yet developed. Fire/life safety costs for BRT stations cannot be estimated at this time. All the requirements for ventilation and safety listed below are minimum requirements.

Ventilation for the flyer stop is determined based on long-term passenger exposure to background CO levels at roadway level during congested traffic conditions. For this reason, supplemental ventilation needs to be provided to the platform. The supplemental ventilation is to be provided by a vent building located adjacent the elevator shaft

The bus platform is to be provided with fire protection by both standpipes and fire extinguishers. Emergency egress for the bus platform should be away from the platform in the direction of bus movement.

6.6 LID AT 84TH AVENUE NE CROSSING (EVERGREEN POINT ROAD)

The tunnel section for EIS Alternatives 3 and 4 includes six or eight lanes at 12 feet per lane with 10-foot shoulders plus the westbound on-ramp for a maximum width of 220 feet. The tunnel is approximately 500 feet long. This lid is located in a sag vertical curve with a nearly level entrance grade and an exit grade of +1.7 percent.

These lanes do not require ventilation for fire life-safety purposes or for normal operating purposes because, at 500 feet long, this lid is self-ventilating. During emergencies, motorists escape to safety via tunnel portals.

Traffic control would require means to stop approaching traffic from entering the lid.

A standpipe, portable fire extinguishers, and communications equipment are to be provided in the lid.

Emergency egress is located at the portals.

6.7 LID AT 92ND AVENUE NE CROSSING

The tunnel section for EIS Alternatives 3 and 4 includes either six or eight lanes at 12 feet per lane with 10-foot shoulders and a flyer stop, for a total width of 188 feet and 212 feet, respectively. The tunnel is approximately 500 feet long, with an eastbound +4 percent grade.

These lanes do not require ventilation for fire life-safety purposes or for normal operating purposes because, at 500 feet long, the lid is self-ventilating. During emergencies, motorists escape to safety via tunnel portals.

Traffic control would require means to stop approaching traffic from entering the lid.

A standpipe, portable fire extinguishers, and communications equipment are to be provided in the lid.

Emergency egress is located at the portals or platform stairways.

The 92nd Avenue NE Crossing also has a flyer stop. The bus platform is at the same elevation as the mainline traffic (at below grade location) and is served as a minimum by stairways and elevator access for handicapped users.

No typical conceptual design for BRT stations located under lids has been developed. Only probable footprint requirements for BRT stations have been identified to date. Therefore, system requirements for BRT station ventilation facilities and emergency ingress and egress have not yet developed. Fire/life safety costs for BRT stations cannot be estimated at this time. All the requirements for ventilation and safety listed below are minimum requirements.

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The bus platform is to be provided fire protection by both standpipes and fire extinguishers. Emergency egress for the bus platform should be away from the platform in the direction of bus movement.

7. CONCLUSIONS AND RECOMMENDATIONS

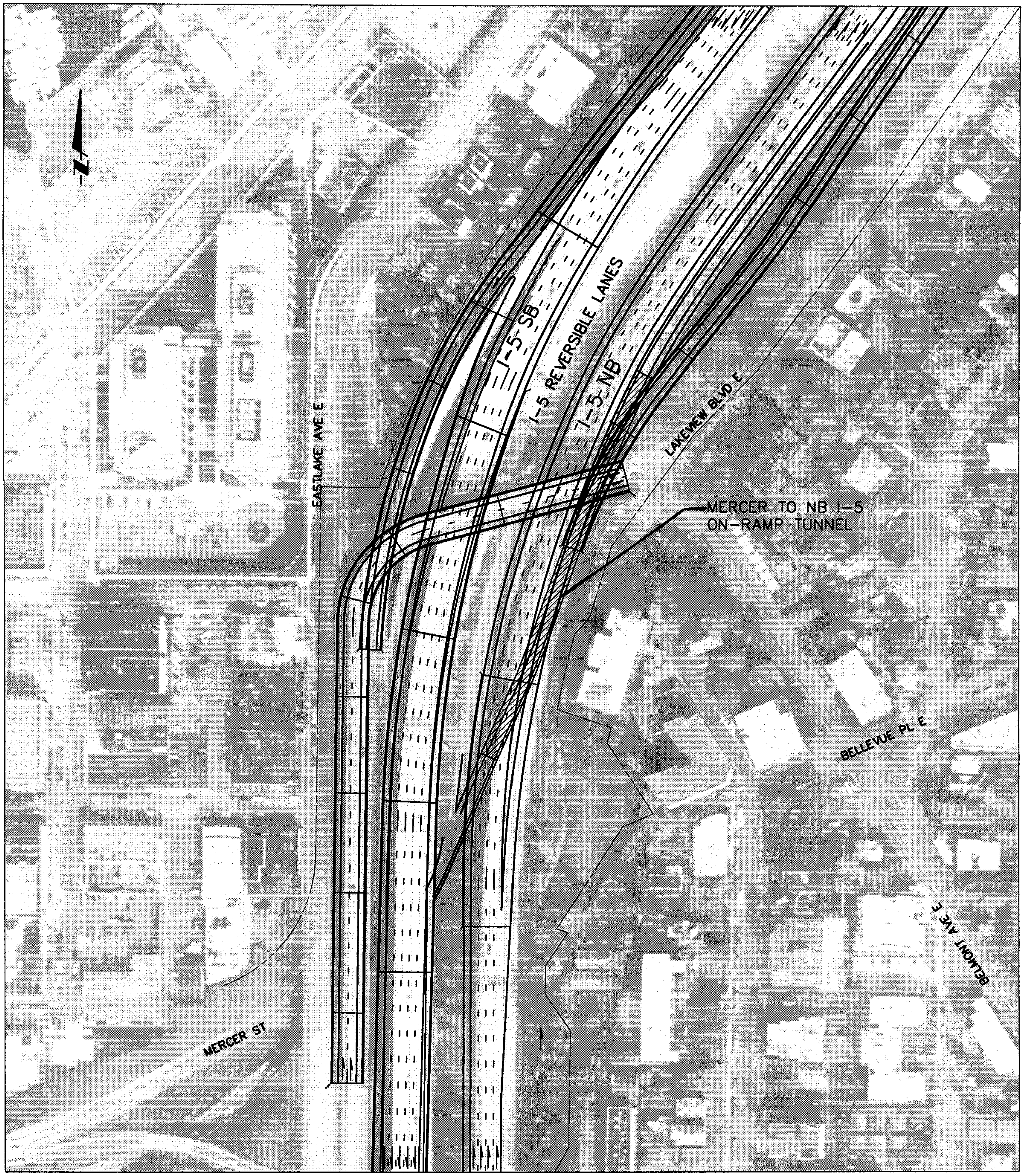
The lids along the Trans-Lake Washington Corridor do not require mechanical ventilation systems. Preliminary analysis indicates that lids at 500 feet in length can be self-ventilating. The length of the lids conforms to the 500-foot recommendation to eliminate ventilation equipment.

All but one of the tunnels that require ventilation are for single-lane tunnels with one-directional traffic movement having minimum cross-sectional areas and minimum overall tunnel width. This results in smaller facilities to support smaller fan systems and equipment requirements.

The Montlake Tunnel identified for EIS Alternative 4 is a major tunnel with two lanes in both directions and a deep section of tunnel under the Lake Washington ship canal. This tunnel is unique in that the ventilation concept includes two types of systems, one for extraction of smoke and hot gases in the event of a fire emergency and one to provide longitudinal movement during normal operation. The second system is necessary as a result of the design fire load, steep grades associated with the tunnel (up to 11 percent), and a response time that is typically up to several minutes based on detection, verification, and response. The jet fans maintain airflow in the desired direction of travel and reduce the time necessary to implement effective smoke control.

All tunnels and lids were reviewed for safety. Selected systems and equipment would be provided for ventilation and life safety.

The flyer stops located at the lids were reviewed for safety. Ventilation needs to be provided at the platform level. Access is, at a minimum, via stairway and elevators. Fire-fighting equipment includes standpipe systems and fire extinguishers.



FILE: 04A-SR5-J LID AT MERCER
DATE: 08/16/02

0 50 100
SCALE IN FEET

DRAWING: 04A-SR5-J AT MERCER
SHEET: 1 OF 8

LEGEND:

- HIGH OCCUPANCY VEHICLE LANE
- HIGH CAPACITY TRANSIT
- TUNNEL/VENTILATION STRUCTURE
- LID
- SIGNALIZED INTERSECTION
- TRAFFIC FLOW

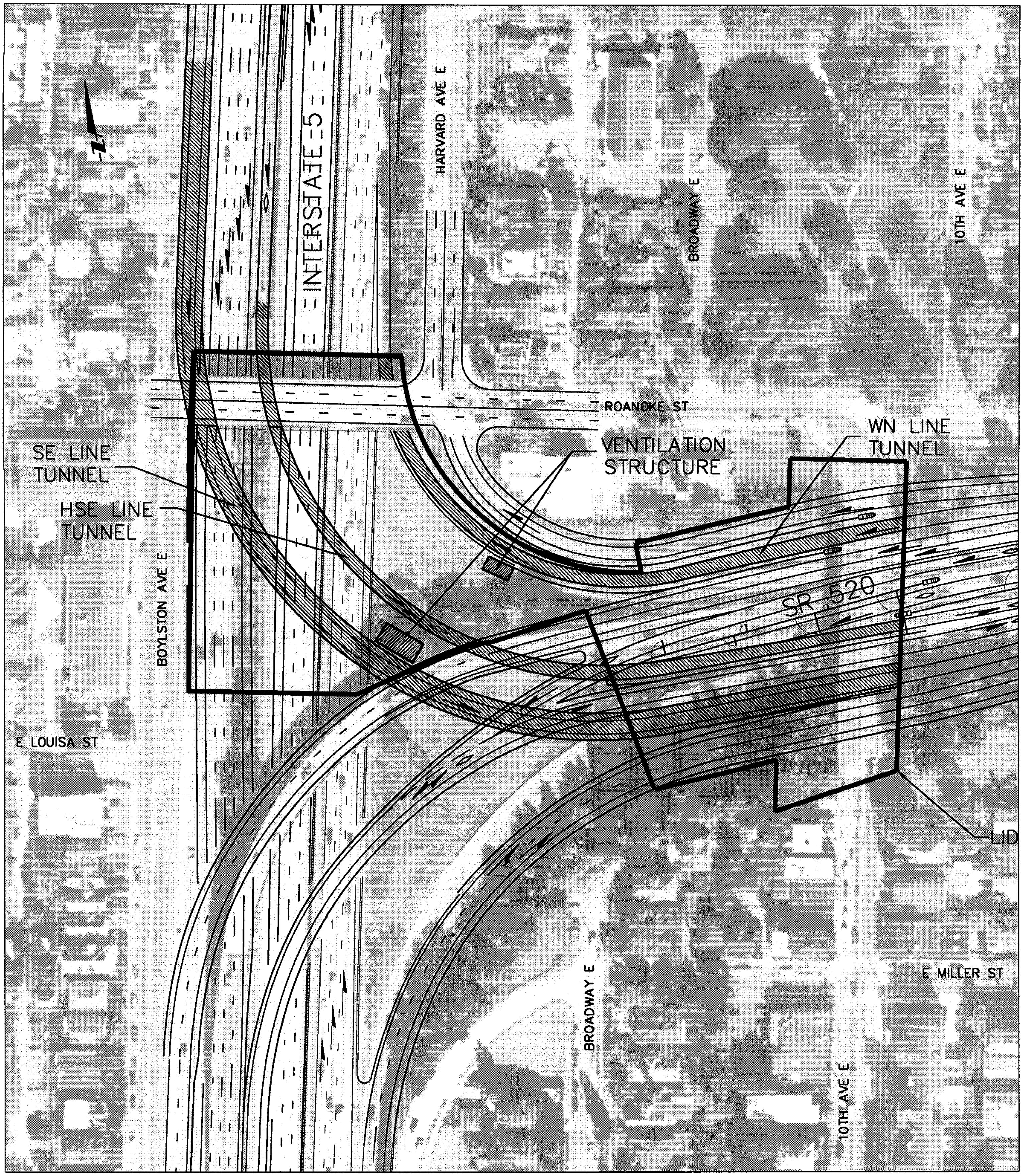
Trans-Lake Washington Project

ALTERNATIVE 4
FIGURE 1 - NORTHBOUND I-5 AT MERCER CORRIDOR

Trans Lake

SOUNDTRANSIT

Washington State
Department of Transportation



FILE: 04A-SR5-J LID AT SR520
DATE: 05/28/02

0 50 100
SCALE IN FEET

LEGEND:

- HIGH OCCUPANCY VEHICLE LANE
- HIGH CAPACITY TRANSIT
- TUNNEL/VENTILATION STRUCTURE
- LID
- SIGNALIZED INTERSECTION
- TRAFFIC FLOW

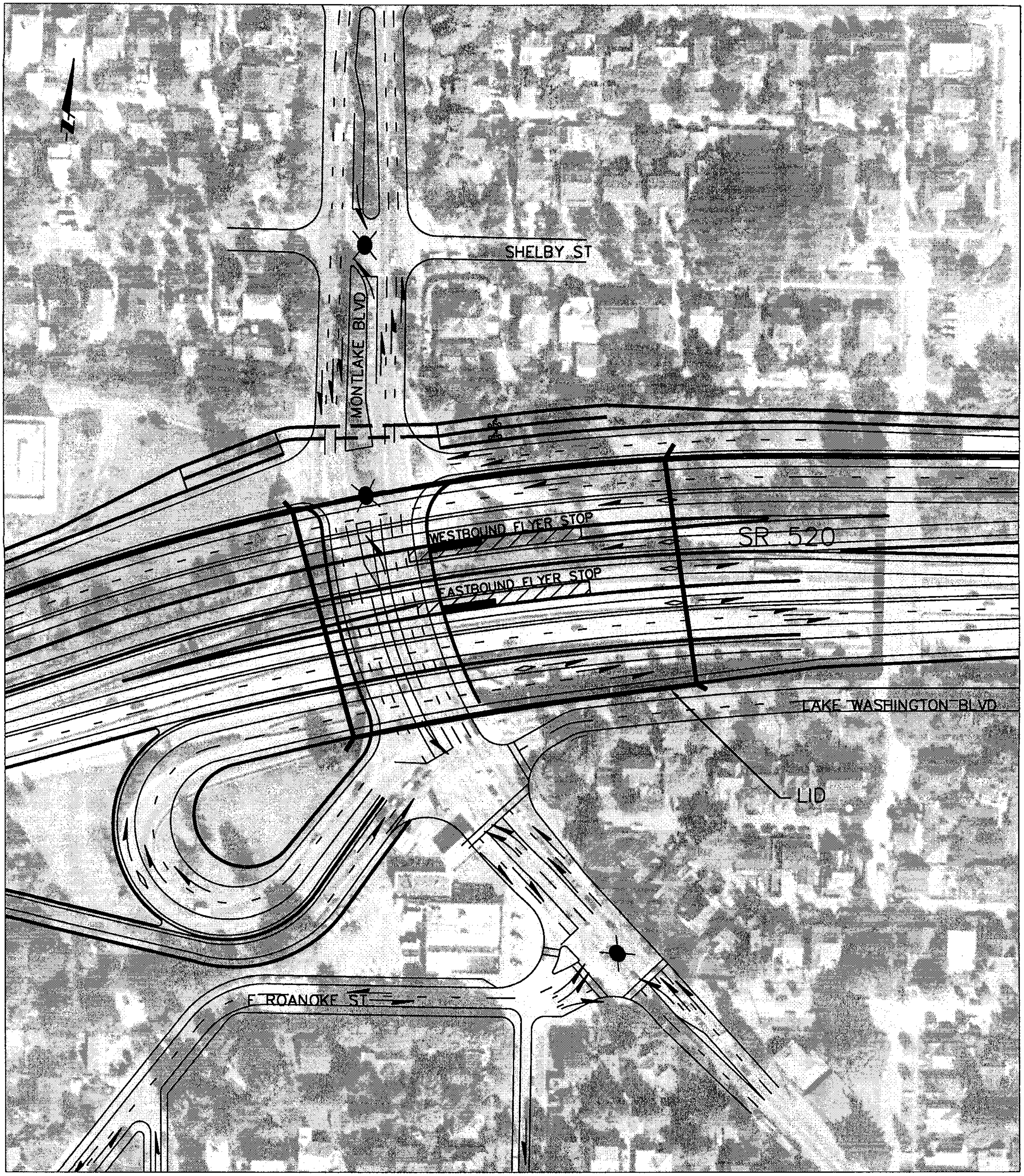
Trans-Lake Washington Project

ALTERNATIVE 4
FIGURE 2
SR 520 AND I-5 INTERCHANGE

DRAWING: 04A-SR5-J LID
SHEET: 2 OF 8

Sound Transit

Washington State Department of Transportation



FILE: 04A-SR520 LID at Montlake
DATE: 08/16/02

0 50 100
SCALE IN FEET

DRAWING: 04A-SR520 LID
SHEET: 3 OF 8

LEGEND:

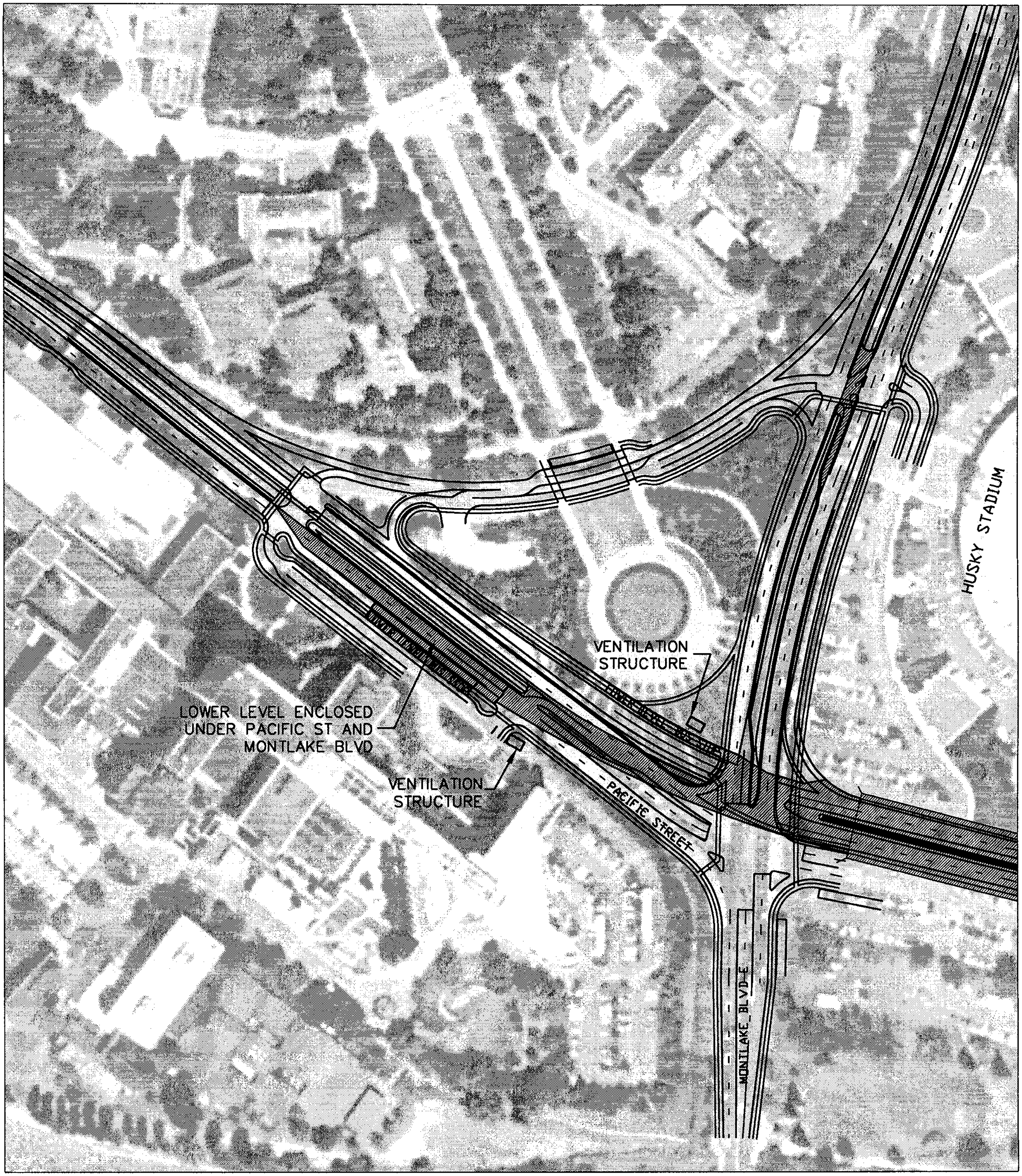
- HIGH OCCUPANCY VEHICLE LANE
- HIGH CAPACITY TRANSIT
- TUNNEL/VENTILATION STRUCTURE
- LID
- SIGNALIZED INTERSECTION
- TRAFFIC FLOW

Trans-Lake Washington Project

ALTERNATIVE 4
FIGURE 3A
SR 520 AT MONTLAKE BLVD I/C

Sound Transit

Washington State Department of Transportation



FILE: 04A-SR520-PACIFIC&MONTLAKE
DATE: 06/19/02

0 100 200
SCALE IN FEET

LEGEND:

- HIGH OCCUPANCY VEHICLE LANE
- HIGH CAPACITY TRANSIT
- TUNNEL/VENTILATION STRUCTURE
- LID
- SIGNALIZED INTERSECTION
- TRAFFIC FLOW

Trans Lake

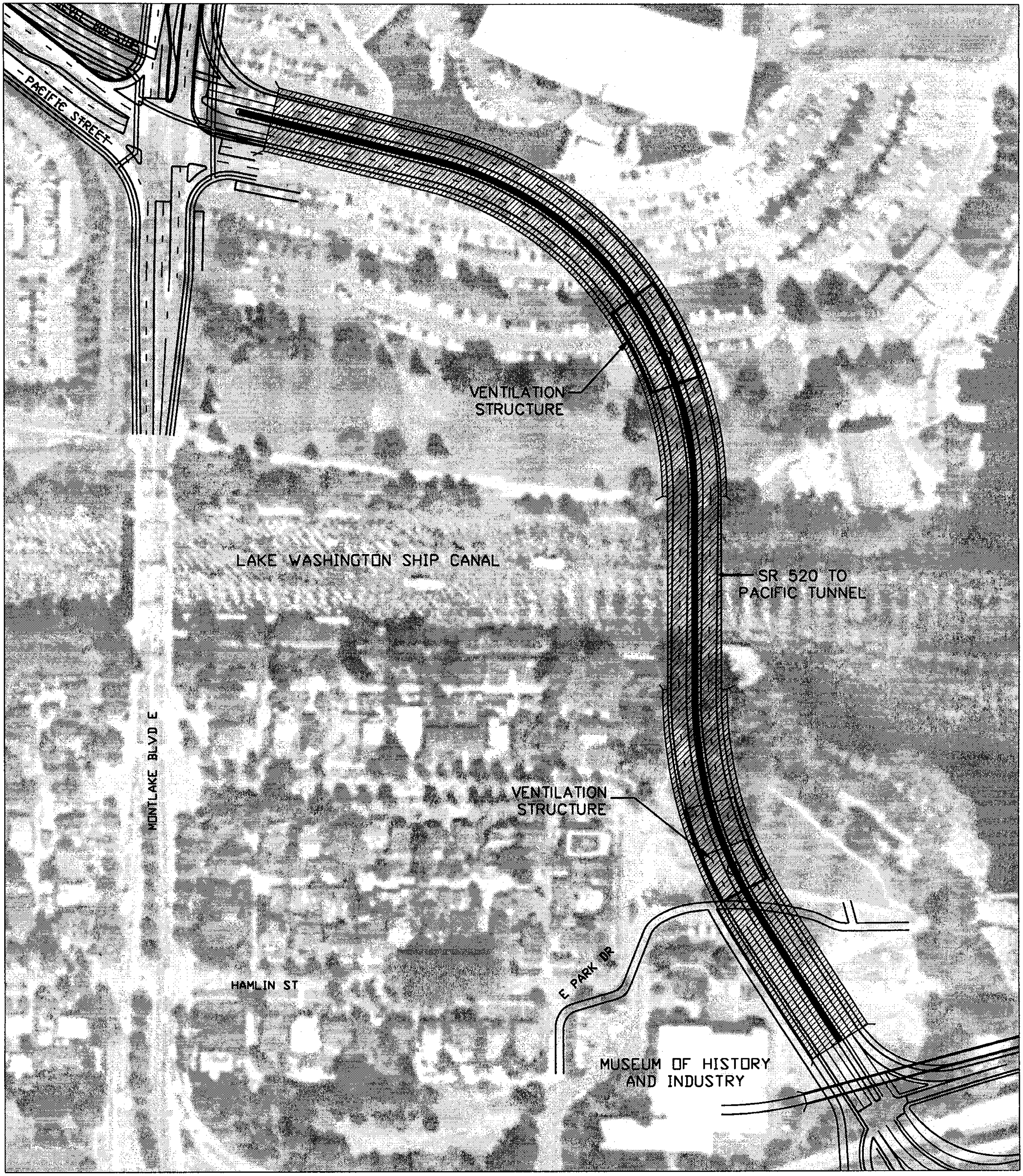
Trans-Lake Washington Project

ALTERNATIVE 4
FIGURE 3B
MONTLAKE BLVD / PACIFIC ST INTERCHANGE

DRAWING: 04A-PACIFIC
SHEET: 4 OF 8

SOUND TRANSIT

Washington State Department of Transportation



FILE: 04A-SR520-PACIFIC&MONTLAKE
DATE: 06/19/02

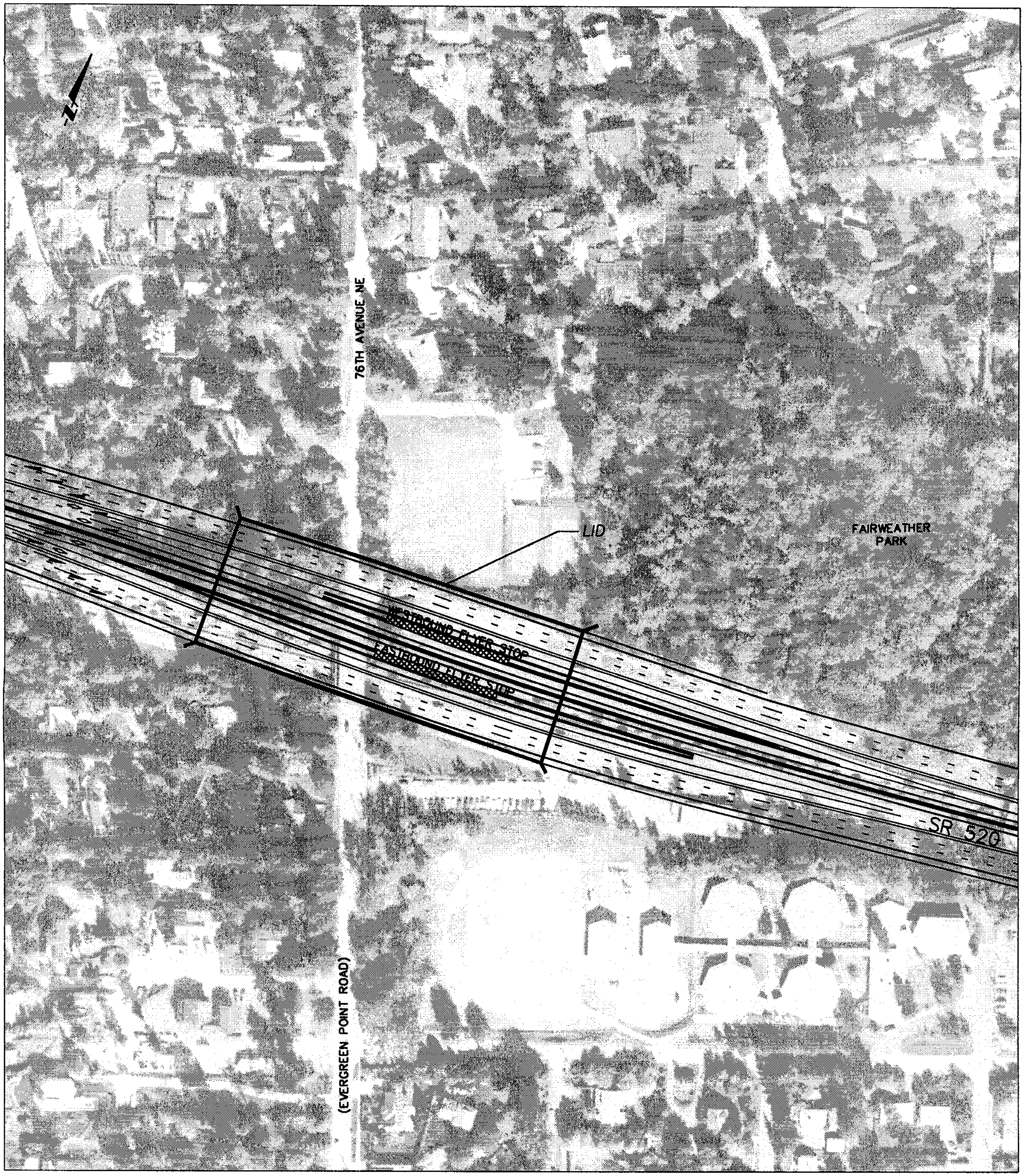
0 100 200
SCALE IN FEET

LEGEND:
- HIGH OCCUPANCY VEHICLE LANE
- HIGH CAPACITY TRANSIT
- TUNNEL/VENTILATION STRUCTURE
- LID
- SIGNALIZED INTERSECTION
- TRAFFIC FLOW

Trans-Lake Washington Project
ALTERNATIVE 4
FIGURE 3C
MONTLAKE AREA - PACIFIC ST. CONNECTION TO SR520

DRAWING: 04A-PACIFIC
SHEET: 5 OF 8

SOUNDTRANSIT
Washington State Department of Transportation



FILE: 04A-SR520-76TH UNDERCROSSING
DATE: 08/19/20

0 50 100
SCALE IN FEET

DRAWING: 04A-SR520-76TH
SHEET: 6 OF 8

LEGEND:

- HIGH OCCUPANCY VEHICLE LANE
- HIGH CAPACITY TRANSIT
- TUNNEL/VENTILATION STRUCTURE
- LID
- SIGNALIZED INTERSECTION
- TRAFFIC FLOW

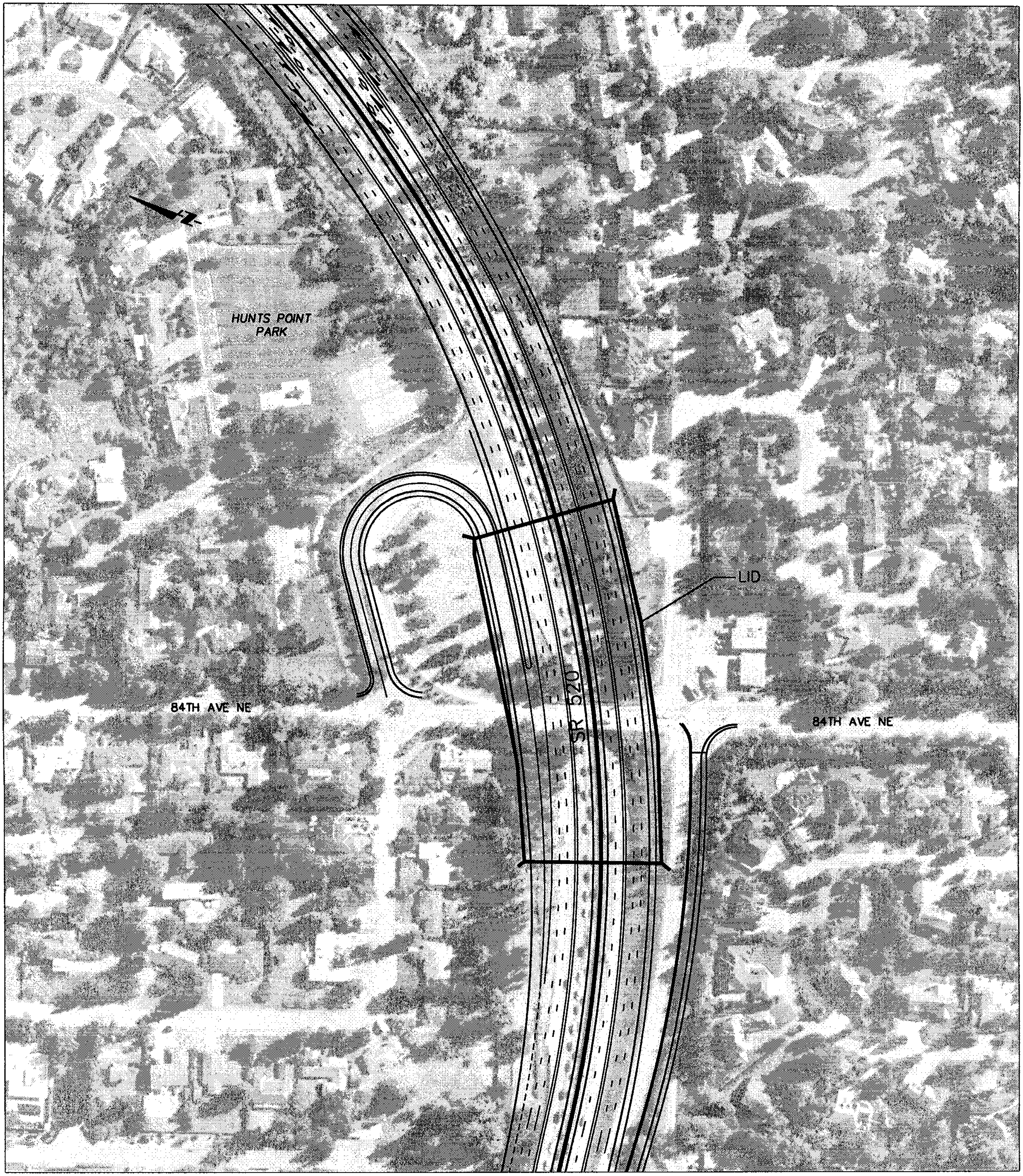
Trans-Lake Washington Project

ALTERNATIVE 4 - FIGURE 4
76TH AVE NE UNDERCROSSING
EVERGREEN POINT ROAD

Trans Lake

SOUND TRANSIT

Washington State Department of Transportation



FILE: 04A-SR520-84TH LID
DATE: 08/16/02

0 50 100
SCALE IN FEET

DRAWING: 04A-SR520-84TH
SHEET: 7 OF 8

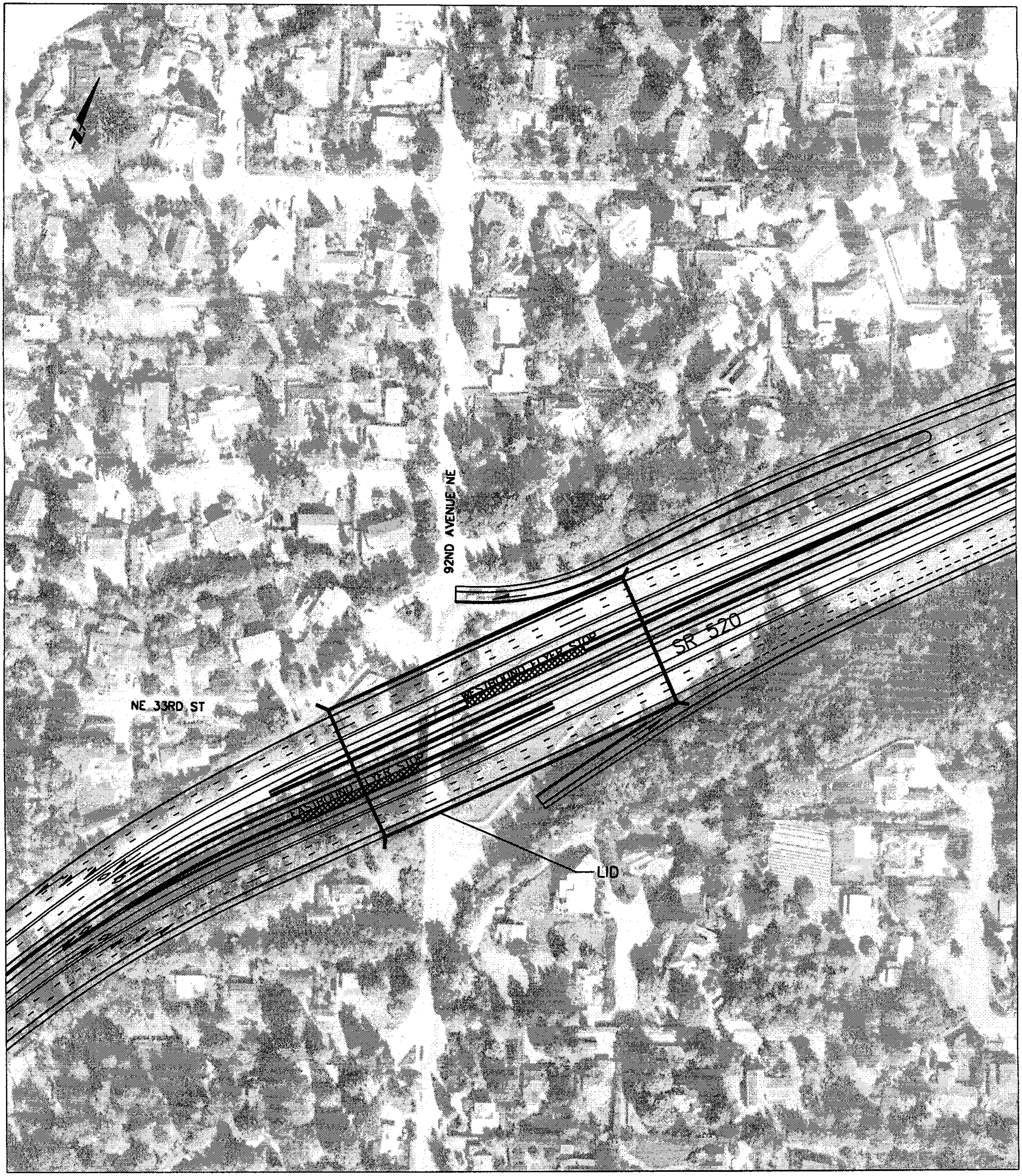
LEGEND:
- HIGH OCCUPANCY VEHICLE LANE
- HIGH CAPACITY TRANSIT
- TUNNEL/VENTILATION STRUCTURE
- LID
- SIGNALIZED INTERSECTION
- TRAFFIC FLOW

Trans Lake

Trans-Lake Washington Project
ALTERNATIVE 4
FIGURE 5
84TH AVE NE UNDERCROSSING

SOUND TRANSIT

Washington State Department of Transportation



FILE: 04A-SR520-92ND LID
DATE: 08/19/02

DRAWING: 04A-SR520-92ND
SHEET: 8 OF 8

0 50 100
SCALE IN FEET

LEGEND:
HIGH OCCUPANCY VEHICLE LANE
HIGH CAPACITY TRANSIT
TUNNEL/VENTILATION STRUCTURE
LID
SIGNALIZED INTERSECTION
TRAFFIC FLOW

Trans Lake

Trans-Lake Washington Project

ALTERNATIVE 4
FIGURE 6
92ND AVE NE UNDERCROSSING

SOUND TRANSIT

Washington State Department of Transportation